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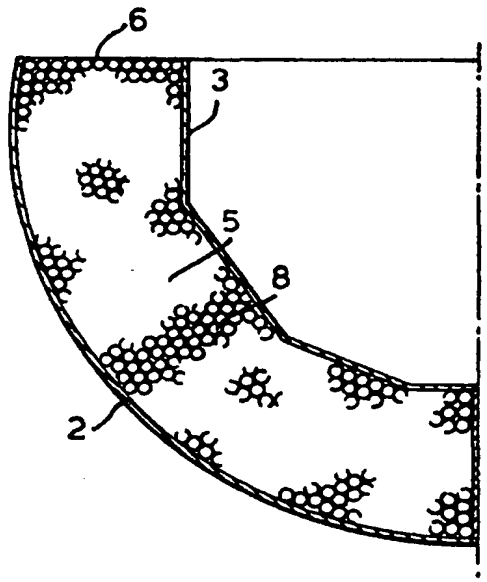
(54) Title: ENERGY ABSORBING STRUCTURES

(57) Abstract

A multiple hull for a ship, comprising at least two hull skins (2, 3) maintained in a spaced apart relationship by bulk heads (4, 7) and describing voids (5) filled with energy absorbing elements (8) designed to deform in response to impact or pressure loading.



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ENERGY ABSORBING STRUCTURES

This invention relates to the field of mechanical structures designed to withstand deformations, and more particularly, but not exclusively, to the field of ship hull protection.

In the field of modern ship and boat design a wide range of different techniques have been employed to offer impact based protection to the hull, to maintain both structural integrity and indeed buoyancy. State of the art designs provide for hull protection by utilising techniques such as twin skin designs, multiple hull structure designs and various side impact protection systems based upon the absorption of deformation based energy by the controlled collapse of internal structural members.

PCT Publication No. WO 94/26585 describes a method and device for the installation of a double hull protection system providing increased energy absorption characteristics via the utilisation of trusslike members arranged so as to provide support to the auxiliary hull shell. The provision of this type of energy absorbing structure requires a complex geometric arrangement of structural support members within the void created between the inner and outer hulls, and therefore can add significant penalties in terms of both weight and design complication thereby resulting in a potentially reduced load carrying capability and increased build and maintenance costs.

The object of our invention is to provide a method and apparatus to improve the energy absorption characteristics of multiple hull designed ships, utilising the mechanical characteristics of state of the art hull design with the addition of novel inter-skin void filling energy absorbing members.

Accordingly there is provided a multiple hull for a ship, designed to reduced structural deformations and damage associated with impact or

pressure loading applied to the outer hull of said ship, said multiple hull comprising at least two hull skins, said hull skins being maintained in a spaced apart relationship by a plurality of bulk head means thereby describing voids, said voids between said hull skins being substantially filled with energy absorbing element means, said energy absorbing element means being so designed as to deform in response to impact or pressure loading.

A specific embodiment of the invention will now be given by way of example only with reference to the following drawings, in which;

Figure 1 shows a diagrammatic representation of a twin hull ship design;

Figure 2 shows a representation of section A-A as denoted in Figure 1;

Figure 3 shows a representation of a section of inter-hull void filled with energy absorbing material in accordance with the invention; and,

Figures 4a to 4b show a diagrammatic representation of ships hull in accordance with the invention undergoing stages of progressive deformation.

In Figure 1, a ship hull assembly is shown 1 comprising an outer hull skin 2, an inner hull skin 3, and a representative number of transverse bulkheads 4 to providing structural support to the inner and outer hulls, 3, 2.

Figure 2 shows section A-A (Figure 1) indicating the relative locations of the outer hull 2 and inner hull 3 to the ships deck level 6 along with the positioning of the ship centre line longitudinal bulkhead member 7. Additionally, the relative locations of the outer skin 2 and inner skin 3 provide for a void 5 as shown.

Figure 3 shows a representative area of void 5 between the outer and inner skins 2, 3 filled with spherical energy absorbing elements 8.

In an example of twin hulled ship design incorporating our invention, Figure 5a shows the double skinned hull 2, 3 in its normal operating configuration, with the void 5 filled with energy absorbing elements. To maximise the energy absorbing characteristics offered by the use of the void filling elements 8, a design in accordance with the invention will comprise a tough strong outer skin 2 forming the outer shape of the ship 1. This itself absorbing some levels of energy and resisting deformation and tearing thereby maintaining buoyancy. Additionally, the transverse watertight bulkheads 4 are required to be tough and compliant to provide support to the outer skin along with void 8 sub-division, thereby locating and retaining the buoyant energy absorption elements within localised areas of the void 8 and permitting the outer skin to deform whilst minimising strain levels. The inner skin 3 is required to be made tough and structurally stiff to help contain the buoyant energy absorption elements and to resist their movement forming a watertight boundary.

The key characteristics of the buoyant energy absorption elements is that they will deform at forces just below those which will apply large local deformities to the outer skin, or large deformations to the inner skin whilst remaining buoyant. The energy elements may be preferably metallic or alternatively be constructed using other materials, including composites, which exhibit the required properties. The outer and inner skins 2, 3 will be separated by large distances depending on the size of the impact loading or deformation to be resisted. The spaces between the inner and outer skins 3, 2 and pairs of bulkheads 4 will be substantially filled with buoyant energy absorbing elements, and either part flooded with water, or bound in a suitable matrix.

Figures 4a to 4e show a typical sequence of events surrounding impact type deformable damage to the hull of a ship having a design in accordance with the invention, where the element of the hull subjected to the loading is below the water line.

Figure 4a shows the initial shape of a section of the hull 1 comprising both outer and inner skins 2, 3 a centre line longitudinal bulkhead 7 and a representative section of inter-skin void 5 containing energy absorbing elements 8. In Figure 4b, the loading the outer hull skin 2 produces a small deformation of the skin 10 along with deformation of some energy absorbing elements in the vicinity of the impact or explosion 11. At this time, the inner skin 3 sees virtually no loading, due to the energy absorption characteristics of both the outer skin 2 and the deforming energy absorption elements 8 in the localised region 11. Figure 4c shows the next stage in the deformation characteristics of the hull design, the outer skin 2 being heavily deformed over an increased region 12 and accordingly an increased number of energy absorption elements 8 become deformed thereby absorbing an increasing amount of deformation energy throughout the region 12. At this advanced stage of deformation, the inner skin 3 begins to see load transmitted from the deformed region 12 by the compression of the energy absorption elements contained between the two skins and therefore begins to deform accordingly over an initial area 13. Figure 4d shows a further advanced stage of ships hull deformation wherein the outer skin 2 is now deformed over an increased region 14 resulting in rupture of said skin 15 and an associated increasing number of energy absorbing elements being substantially deformed thereby absorbing an increasing amount of deformation energy. Accordingly, the inner skin 3 deforms over a larger region 16 seeing load transmitted by the energy absorption elements contained between the two regions 14, 16. The final figure in the

sequence, Figure 4e, shows the whole deformation at a very advanced state, wherein the outer skin 2 is deformed over a region 17, this outer skin 2 containing significant ruptures 19 resulting in the subsequent inability of the outer skin 2 to provide any further mechanical deflection resistance. The energy absorbing elements 8 contained within the region bounded by the outer skin 17 and inner skin deformation 18 would at this stage have absorbed substantially all of the energy possible, and therefore will be transmitting any further deflection energy directly to the inner skin 3 over said region 18. The design of the inner skin 3 is such that the mechanical toughness and stiffness characteristics are such that the skin 2 should contain the buoyant energy absorbing elements and delay as far as possible penetration or rupture of the skin 2 which would compromise the function of the inner watertight boundary.

Due to the transverse bulkhead segmentation characteristics of the twin hull design, following an event as depicted in 4a to 4e, the structure is expected to have suffered large deformations in the outer skin, and some permanent compression of some of the buoyant energy absorbers will have occurred. Hence, some reduction of their buoyancy will result and accordingly a reduction of hull volumes (and therefore buoyancy) will occur. The design characteristics are such that the segmented nature of the hull design result in the craft as a whole experiencing little change of draft, heel or trim.

The energy absorbing characteristics of the invention can easily be applied to other structures which may be subject to impact or pressure loading, including but not limited to aircraft and motor vehicles.

CLAIMS

1. A multiple hull for a ship said multiple hull comprising at least two hull skins, said hull skins being maintained in a spaced apart relationship by a plurality of bulk head means thereby describing voids, said voids between said hull skins being substantially filled with energy absorbing element means, said energy absorbing element means being so designed as to deform in response to impact or pressure loading.
2. A multiple hull for a ship as claimed in claim 1, wherein said energy absorbing element means are designed to deform at forces just below those which will apply large local deformations to the outer hull skin, or large deformations to the inner hull skin.
3. A multiple hull for a ship as claimed in claims 1 and 2 above, wherein said buoyant energy absorbing element means are spherical.
4. A multiple hull for a ship as claimed in claims 1, 2 and 3 above, wherein the void between said hull skins is substantially filled with said energy absorbing element means and partially flooded with water.
5. A multiple hull for a ship as claimed in claims 1, 2 and 3 above, wherein the voids between said hull skins are substantially filled with energy absorbing element means which are bound in a matrix material.
6. A multiple hull for a ship as claimed in claims 1 to 5 above, wherein said energy absorbing element means are metallic.
7. A multiple hull for a ship substantially as hereinbefore described with reference to the accompanying drawings

Fig.4c.

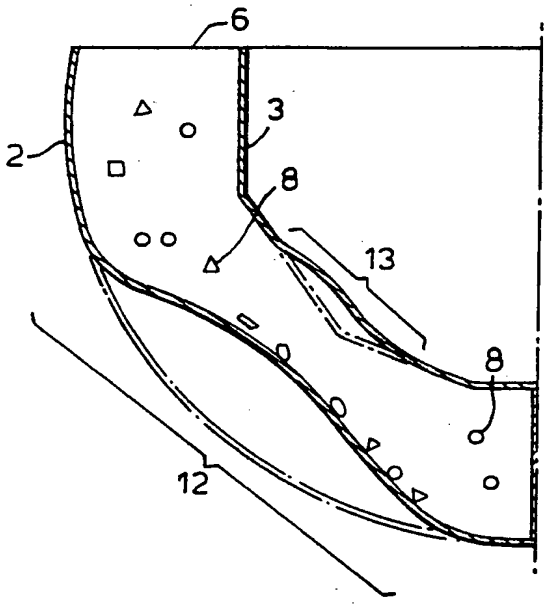


Fig.4d.

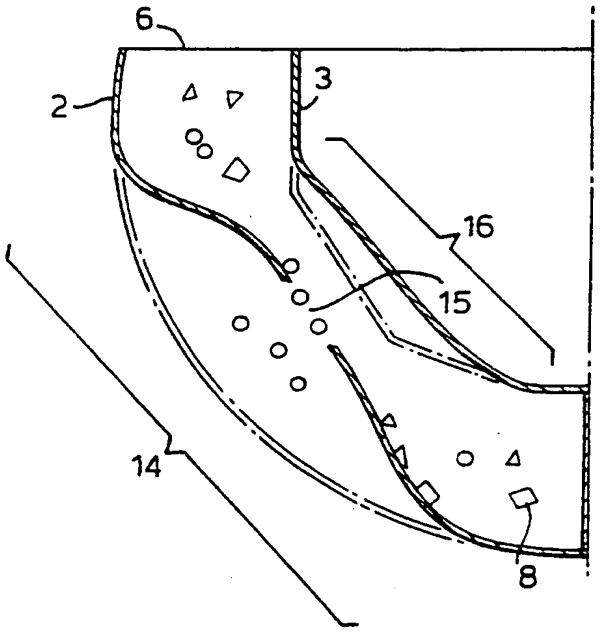


Fig.4e.

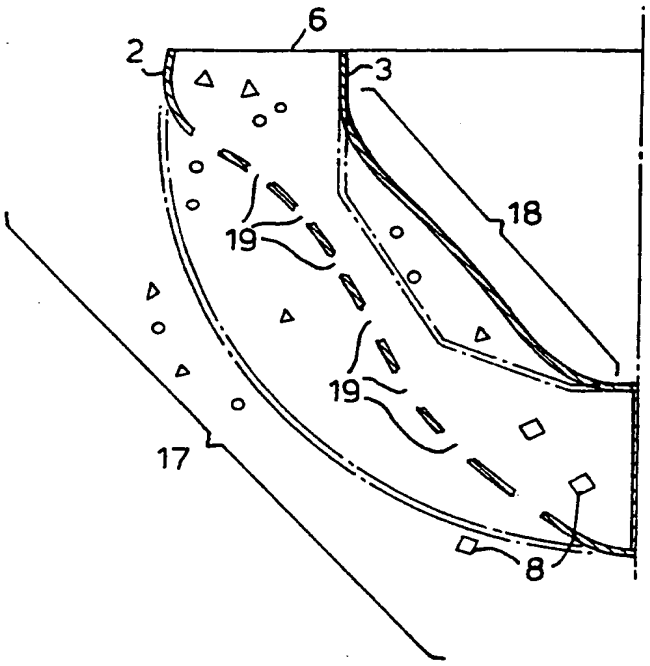


Fig.1.

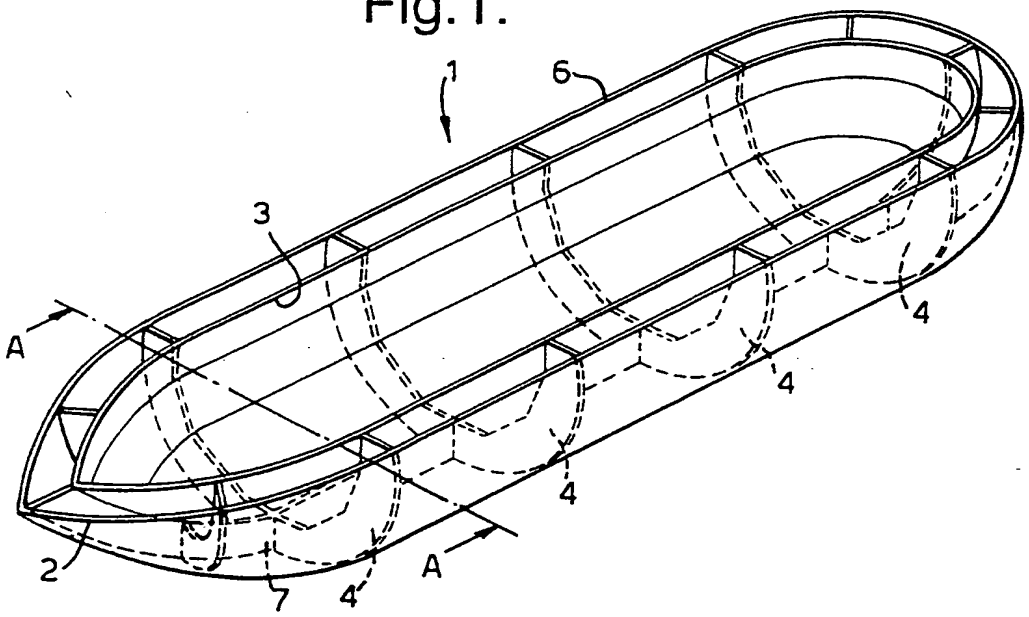
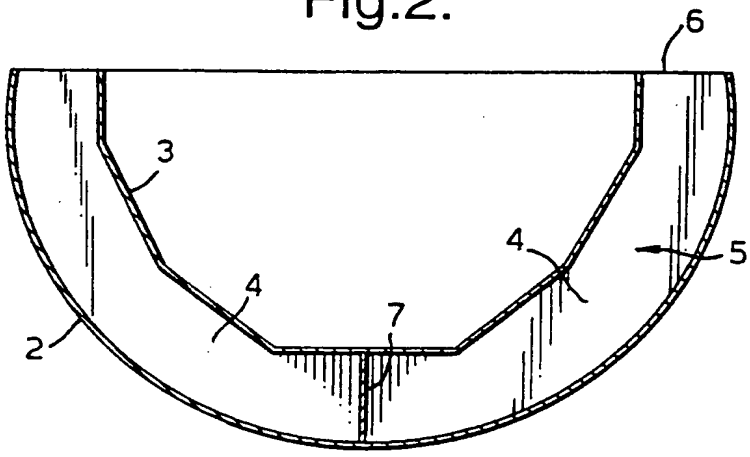


Fig.2.



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B63B43/18 B63B3/20 //B63B25/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 803 004 A (SWANN RONALD F ET AL) 8 September 1998 (1998-09-08) claim 1; figures 1-4,6-7C	1,3,5,7
Y	column 2, line 20 - line 38 column 5, line 8 - line 53 column 6, line 8 - line 28	6
Y	DE 24 62 128 A (TOYO KOHAN CO LTD) 5 February 1976 (1976-02-05) page 1, line 1 - line 15 page 8, line 8 - line 16	6
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 379 711 A (FISCHER EUGENE C ET AL) 10 January 1995 (1995-01-10) abstract; claims 1,8,13,14; figures 3-6 column 4, line 17 - line 30 column 5, line 63 -column 6, line 21 column 8, line 21 - line 50 column 9, line 16 - line 27	1-3,7
X	EP 0 799 764 A (SCHELDE MARITIEM B V) 8 October 1997 (1997-10-08) abstract; claim 1; figures 1,2 column 1, line 58 -column 2, line 12 column 2, line 31 - line 59	1,6,7
X,P	US 5 862 772 A (DAVES TED M ET AL) 26 January 1999 (1999-01-26) claims 1,9; figures 8-9C column 4, line 21 - line 56 column 5, line 54 - line 67 column 6, line 55 -column 7, line 7	1-3,5,7
A	US 5 613 460 A (STALLARD III CLINTON W) 25 March 1997 (1997-03-25) claims 1,3-7,12; figure 2 column 2, line 24 - line 39 column 2, line 47 -column 3, line 22	1-7
A	DE 44 32 234 A (KOCH FRIEDRICH) 30 May 1996 (1996-05-30) the whole document	1,4,7
A	WO 94 26585 A (SPECIAL PROJECTS RESEARCH CORP; HART, DAVID W ET AL.) 24 November 1994 (1994-11-24) cited in the application abstract; claims 1,7,23; figures 1-3,16,17 page 1, line 11 - line 14 page 8, line 12 -page 9, line 17	1,5,7
A	US 2 405 590 A (MASON WARREN P) 13 August 1946 (1946-08-13) figures 1,2 column 3, line 30 - line 50	1,7

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 99/03840

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5803004 A	08-09-1998	NONE	
DE 2462128 A	05-02-1976	NONE	
US 5379711 A	10-01-1995	NONE	
EP 0799764 A	08-10-1997	NL 1002756 C	02-10-1997
US 5862772 A	26-01-1999	NONE	
US 5613460 A	25-03-1997	NONE	
DE 4432234 A	30-05-1996	NONE	
WO 9426585 A	24-11-1994	NONE	
US 2405590 A	13-08-1946	NONE	